ANSWER TO REVIEWER'S COMMENTS

"On the wind stress formulation over shallow waters in atmospheric models" Pedro A. Jiménez and Jimy Dudhia.

Reviewer 1

GENERAL COMMENT

Recommendation: Acceptable for publication following minor revisions

The authors demonstrate that the agreement between observed and simulated low-level wind speeds at a research platform located in shallow seas can be improved by increasing the parameterized roughness of the ocean surface, relative to the roughness used over open oceans with deeper bathymetry. The authors hypothesize that their results will be relevant to many other models, since these models assume the same relationship between near-surface wind speed and ocean roughness regardless of the depth of the ocean. The authors recommend that atmospheric models include a bathymetric dataset as input, to allow for increased roughness in shallower seas. These results are highly relevant to the modelling community and have the potential to improve low-level wind forecasts in coastal regions, with obvious implications for the energy sector (e.g., oil platforms and wind turbines).

While I appreciate that the manuscript is brief and the authors state their conclusions clearly, I recommend that the authors take the time and space to include additional information on their simulations and analysis methods. As it stands, it would be impossible for another scientist to reproduce the authors' experiments and results. I also have some minor comments on the phrasing of several sentences, although overall the article is well-written.

ANSWER

We appreciate the positive perspective that this reviewer has on the manuscript and would like to thank the time he/she devoted to review it. We have reproduced below each of the comments and we explain how we will address them in the new version of the mnauscript.

MINOR REVISIONS RECOMMENDED:

COMMENT 1

The authors claim that most models use the COARE algorithm to relate the low-level wind speed and the ocean roughness (e.g., page 9065, lines 2324). However, they provide no evidence

for this. I appreciate that it may be difficult to find published details for the details of individual model parameterizations, but even a few examples would be welcome. Can the authors provide some citations to back up their assertion?

ANSWER

This sentence is on the context of the "observational evidence" that briefly review the state of the science. The sentence mentioned by the reviewer states " Nowadays, the Coupled Ocean-Atmosphere Response Experiment (COARE) algorithm provides the most widely used relationship". Here we rely in Foreman and Emeis (2010) cited on the manuscript. Note that this do not necessary mean the most widely used relationship in atmospheric models. Actually, both the ECMWF and GFS models use a Charnock relationship like Eq 1. This is in agreement with the phrase on page 9066 lines 11-13: "*regional and global atmospheric models widely use a roughness formulation such as Eq. (1) with a Charnock parameter valid for the open ocean.*"

We will avoid potential interpretations in the direction that the reviewer suggested by 1) Adding the reference of Foreman and Emeis (2010) to the phrase that state the the COARE algorithm is the most widely used relationship; and 2) by adding "*(e.g. ECMWF and GFS models)*" after the phrase that refers to the atmospheric models.

COMMENT 2

Page 9066, lines 25-27: Please give the heights of the levels at which data were obtained from the platform. Also, please give the latitude and longitude coordinates of the platform, rather than the vague description of "48 km from the German coast".

ANSWER

The wind speed sensors are located at 33 m, 40 m, 50 m, 60 m, 70 m, 80, 90, and 100 m. We will add this information at the end of line 25 on page 9066: "... *at a total of eight levels within the first 100 m of the atmosphere (i.e. 33 m, 40 m, 50 m, 60 m, 70 m, 80 m 90 m and 100 m)*".

The latitude and longitude of the tower are N54.01 degrees and E6.59 degrees. We will add this information on page 9066, line 27: "*The observations were acquired at the research platform FINO 1 located at about 48 km from the German coast (54.01 degrees N by 6.59 degrees E) with ...*"

COMMENT 3

The authors need to provide further detail on the design of their simulations and the data extracted from them, so that another scientist could reproduce their simulations exactly. Specifically:

a. In regional models such as WRF, the results are often sensitive to the size of the domain. Therefore, it is important for the reader to know the boundaries of the domain that the authors used. Did the domain vary between the three horizontal resolutions tested (27 km, 9 km and 3 km)? Did the authors test the sensitivity of their results to the size of the domain?

b. How long were the sensitivity experiments to horizontal resolution? Did the authors test the entire year (2009) or did they test only a fraction of it?

c. Page 9067, line 3: What does "essentially the same" mean? If the WRF configuration is the same as in another paper, then please say so clearly. Otherwise, please state precisely how the WRF configuration in this study differs from those in the previous papers.

c. When the authors compare data from their WRF experiments to the data from the research platform, do they use only the WRF data from the gridpoint closest to the platform?

ANSWER

a) The 27 km domain has 57 by 60 grid points so the dimensions are 1539 km by 1620 km. It covers the complete North Sea and the eastern part of the Baltic Sea. The size of the domain is a compromise to 1) locate the boundaries far enough so errors propagating from the boundaries do not affect the simulation at the target location; and 2) locate the boundaries close enough to the target location to constrain the atmospheric evolution over the domain to the observed behavior, the re-analysis data (ERA-Interim) used to calculate the initial and boundary conditions. We did not test sensitivities to the domain size. Based on our experience, we will expect similar results to the ones herein presented if we increase the size of the domain.

The nested domains have different size/dimensions. The 9 km domain is nested in the 27 km domain and it is approximately centered on the location of FINO1. It has a square shape of 49 by 49 grid points (441 km by 441 km). The 3 km domain is nested on the 9 km domain and covers both the ocean and coastal areas near FINO1. The domain has a square shape of 52 by 52 grid points (156 km by 156 km). This is a rather standard way to configure limited area models to progressively reach higher horizontal resolutions over a target region. The interaction of the domains is one way so it is possible to compare the results from each of them to quantify the benefit of increasing the horizontal resolution. The coverage of the domains is shown on Figure 1 of this document.

We will modify the text to indicate that the 27 km domain covers the North Sea and the eastern part of the Baltic sea (Page 9067, line 12): "*...were performed at 27 km of horizontal resolution. The domain covers the complete North Sea and the eastern part of the Baltic Sea.*". We will not include Figure 1 in the new version of the manuscript since we preffer not to emphasize the nested domains since results from these domains are not shown in the manuscript.

b) The sensitivity experiments were one year long (2009). We will clarify this on page 9067, line 10: "*Different simulations for the complete year of 2009 were performed at 27, 9 and 3 km with very little sensitivity...* ".

c) The WRF configuration is the same as the articles cited except for a refined vertical resolution near the ground. We will clarify the sentence of page 9067, line 3-4: "*... the WRF simulations are essentially the same as those used in previous studies (Jimenez et al. 2009, 2011a, b), the only difference being the addition of five vertical levels near the Earth surface.*".

d) Yes, we used the simulated wind at the nearest grid point to the research platform. We will clarify this on page 9068, line 3: "*...percentile-percentile comparison in Fig. 1 (red area). The simulated wind at the nearest grid point to FINO 1 is used in the comparison. Clearly, ...*".

COMMENT 4

Page 9067, lines 28-30: The meaning of this sentence was not immediately clear to me. How do timing errors mask systematic errors? I think the authors mean that they are compare only the frequency distributions of the observed and simulated wind speeds, rather than examining whether WRF predicts the correct wind speed at the time it was observed at the platform. That is fine, because this paper is not an assessment of prediction skill. Still, this comment should be clarified, particularly the part about systematic errors.

ANSWER

Yes, we compare only the frequency distributions to avoid timing errors. We will replace the phrase "*To avoid timing errors associated with the tails of the wind speed distribution that can mask systematic errors, we focus on the frequency distribution characteristics only.*" by "*To avoid the influence of timing errors in the simulations, we focus on the frequency distribution characteristics only.*"

COMMENT 5

Section 4 and Figures 1 and 3: I am confused by the authors' references to "percentile-

percentile comparisons" and "percentilepercentile plots" in Figures 1 and 3. The axes of these figures show raw values of wind speed for the platform observations and the WRF simulations; percentiles do not appear anywhere on either figure. How have percentiles been used to compute these figures? Further, does the shading represent the absolute range of the four WRF simulations, or the standard deviation? The authors need to explain exactly how they have produced these figures, so that someone else could use data and reproduce their plots.

ANSWER

We plot the percentiles of the simulation *versus* the precentiles of the observations. The percentiles have the same units as the variable being analyzed in this case wind speed. So we plot the observed percentile 1 versus the modeled percentile 1, the observed percentile 2 versus the modeled percentile 2 and so on. The name percentile-percentile plot (or quantile-quantile plot, QQ plot) is a standard convention. We will add a reference to a book that describes the percentile-percentile plot (page 9068, line 4): "*..., as a percentile-percentile comparison (Wilks, 1995)*".

The shading on Figure 1 represents the absolute range of the four WRF simulations. We will clarify this on the caption of the figure: "*The shaded areas comprise the absolute range of the results from the four different turbulence closures used in...* ".

COMMENT 6

Page 9068, line 24-25: How far is HEXOS from FINO1. "Relatively close proximity" is not particularly scientific language.

ANSWER

We mention in the text that (Page 9068, lines 22-23) " *...HEXOS programme (Janssen, 1997) took place in the vicinity of the Dutch Noordwijk platform...* " . We will add the latitude and longitude of the platform: "*...the Dutch Noordwijk (52.27 degrees N by 4.30 degrees E).*

COMMENT 7

Figure 2: Please add an estimate of the goodness-of-fit between each of the coloured lines and the HEXOS data in panels (a) and (b), so that the reader has a quantification of how well each parameterization fits the observations.

ANSWER

A goodness of fit would add information of the overall fit of the curves to the data. We do

not think this is necessary here. For low wind speeds the three curves are similar. It is for high wind speeds where the differences are more important and the ones that are relevant to correct the biases in the wind speed simulation (Fig. 1). No action will be taken with this comment.

COMMENT 8

Page 9070, lines 12-16: Please state exactly how you have defined stability in this analysis.

ANSWER

The stability has been defined by the simulated stability parameter z/L where L is the Obukhov length. We will add this information on page 9070, line 7: "*...using the standard WRF formulation. Stability is determined with the simulated stability parameter z/L where z is the height of the first model level, the surface layer, and L is the Obukhov length.*"

SENTENCE-LEVEL REVISIONS RECOMMENDED:

COMMENT 9

Page 9065, lines 9: Substitute "this is" for "this being".

ANSWER

We will include this correction in the revised manuscript.

COMMENT 10

Page 9066, lines 7-11: This is a long sentence that took me several attempts to parse. I suggest rewriting it as (starting from line 8): "... but it has been speculated to be either associated with (a) the effects of the ocean bathymetry, which slows the phase speed of the waves, which then become shorter and steeper in an effect known as shoaling (Foreman and Emeis, 2010); or (b) form drag due to short (young) waves (DeCosmo et al., 1996)."

ANSWER

We will rephrase the sentence in the way the reviewer suggests.

COMMENT 11 and 12

Page 9066, line 15: At the end of the line, delete "and" and add "; we" to break up this long sentence.

Page 9067, line 16: "we used a total of 4 different PBL parameterizations" can be written as "we used four PBL parameterizations".

ANSWER

We will include this corrections.

COMMENT 13

Figure 3, caption: "The data used for this each experiment corresponds with the average of the 4 simulations... ". I suspect that the data are the averages of the four simulations, not that they merely "correspond with the average". Please be precise.

ANSWER

Yes, we will say " The data used for each experiment is the average of the four simulations...".

References

Wilks, D. S., 1995: *Statistical Methods in the Atmospheric Sciences*. Academic Press, 467 pp.

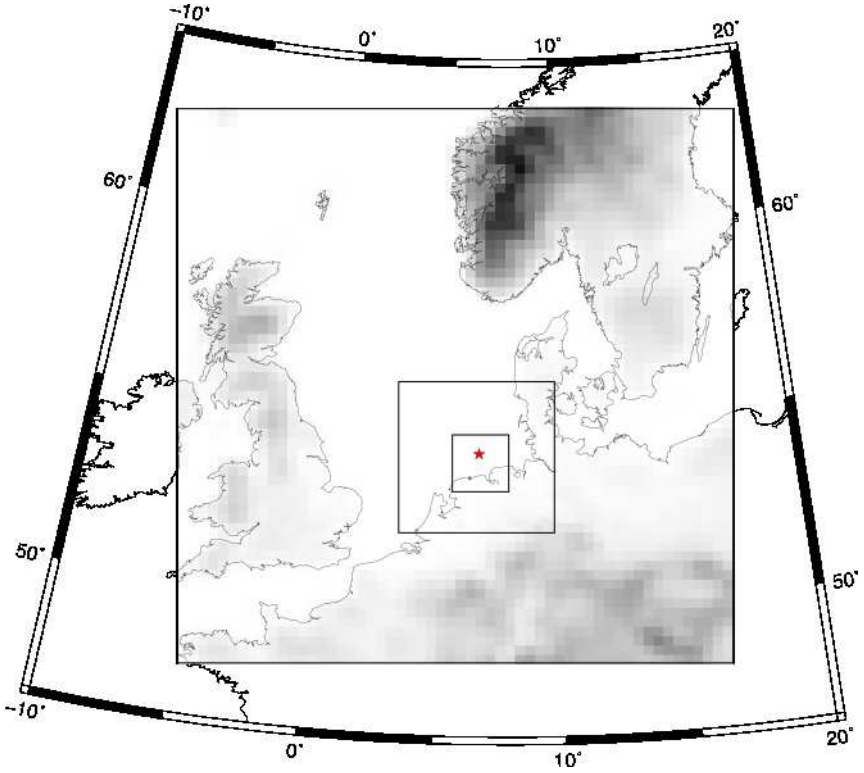

Figure 1: Area covered by the 3 domains (27 km, 9 km and 3 km). The star highlights the location of FINO1.